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HEFEI HUALING ELECTRICS CO.,LTD

Mrs. M. Latrch, Contract Officer
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Subject: Final Report
Reference: Contract Number 98/240, Project Number MP/CPR/98/047

Dear Mrs Latrech

We have the pleasure to submit to you herewith our final report. Subjected to the contract number 98/240 and referring to UNIDO's project Number MP/CPR/98/047. We hope that this draft will satisfy you and you can consider it approval for draft final report. We also enclose our invoice, which has been prepared inaccordance with the contract.

Sincerely Yours
General Manager
Hualing Company

合肥华凌电器有限公司
HEFEI HUALING ELECTRICS CO.,LTD.

Intoduction

This report has been prepared based on Contract with UNIDO and relevant terms of references prepared by UNIDO. The aim of the contract is to develop and convert three models of currently in production, into Ozone Friendly Refrigerant cooling system.

Based on Montreal and People Republic of China agreement, R134a refrigerant was selected as suitable Ozone friendly Refrigerant replacement and an alternative for R12 refrigerant and also Cyclopentane as a substitute for R11.

This change to the cooling system requires significant modification and improvement of cooling system. Due to the enhanced physical and chemical properties of the main components of the cooling circuits must be replaced of adjusted as a consequence of substitution of R12 into R134a.

The new refrigerant has special behavior in mixing with mineral oil and is not miscible with it, thus specially synthetic oil has been produced in order to be solved easily with R134. The new synthetic oil is extremely hydroscopic and absorbs moisture and dirt. Therefore, maximum care in designing and selecting of suitable components must be taken. drier, and compressor are the main items that should be taken into consideration for proper selection.

Since the molecular size of R134a is smaller in comparison with R12, and due to the better thermal conductivity, higner latent heat and also higher coefficient of heat transfer, the size and the power of the compressor is different from what we use as R12 compressor. Thus following changes and redesign of the compressor must be taken into consideration.

1- More Input Power, due to the bigger size of cylinder displacement
2- More Cooling Capacity about 10-25% in LBP type compressors, due to the higher specific volume, and in consequence improvement in performance of LBP type compressor with higher displacement of piston.
3- At HBP compressor an improvement should be done to assure better performance, because of higher thermal properties and lower viscosity (possibly up to 10% at 10% evaporating).
4- Improvement of compressor electromotor winding shield and power.

5- Bigger size of Filter drier, about 40%, in order to prevent eventual blockage of cooling circuits due to the absorption of moisture by synthetic oil.
6- Necessary adjustment of Capillary tube, for better performance, pressures stability and vapor liquid condition of refrigerant. Usually 10% of increase of capillary tube is suggested to prevent high start torque. And better pressure
7- Using Easter Oil, as a replacement of mineral oil.
8- Adjustment of refrigerant charge. Normally 10% of refrigerant charge weight reduction is recommended.
9- Cleanliness

Cleanliness of the plant is associated with experience of the initial installation and its sudsequent need for servicing other than routine.

The procedure for new R134a plant are more stringent than those used for R12, attention being drawn, particularly to good evacuation and charging.

It is vital that the system is not contaminated with chlorinated residues from charging manifolds and vacuum pumps previously used with R11 or r12, or any refrigerant containing chlorine.

The safe level of chlorinated residues is in the region of 200 PPM, but every endeavor should be made to eliminate traces of chlorine to zero.

In application where the plant is to be converted from R12 to R134a the situation is more critical as the installation will contain and possible chlorine residues.

Selection of Components

Due to the significant changes to the cooling system circuit of the appliance burdened, because of substituting R12 with R134a refrigerant. Special consideration must be taken to select proper components. The heart of cooling system is compressor. Therefore or most effort is to chose right compressor to be compatible with the existing cooling system. The aim conversion of the refrigeration system is to minimize necessary changes. Because any additional changes will bear a lot of cost for production. Assuming 10% increase of capillary tube length could make increase of supplying raw materials and therefore higher production cost. The following steps must be taken for conversion of prototypes.

1- Determination of technical specification of models.
2- Calculation of refrigeration load, based on technical data collected.
3- Selection of suitable compressor, based on refrigeration load calculation.
4- Preparation of suitable equipment for charging R134a refrigerant, such as Vacuum Pump, Charging board and leak detectors.
5- Supplying enough R134a refrigerant.
6- Supplying bigger size filter drier, 40% higher than what is used in R12 cooling system.
7- Preparation of hot chamber in accordance with relevant ISO standards. Such as ISO 7173 or 8185, or 5155
8- Accomplishment of performance tests at hot chamber in different ambient temperature, and designated operating condition. Such as;

One) 43 $\pm$ 0.5 °C with 45 – 75% of relative humidity (Tropical Rating).
Two) 38 $\pm$ 0.5 °C with 45 – 75% of relative humidity (Subtropical Rating)
Three) 32 $\pm$ 0.5 °C with 45 – 75% of relative humidity (Standard Condition)
Four) 25 $\pm$ 0.5 °C with 45 – 75% of relative humidity (sub-Normal Condition)
Five) 18 $\pm$ 0.5 °C with 45 – 75% of relative humidity (Cooled Condition)

9- Performing tests for pull down, continuos run, cyclic run and, energy consumption, in order to do necessary adjustment to the refrigeration system circuits.
10- Evaluating test results for applying necessary changes to the cooling system and optimize the system component selection.
11- Selection of components in accordance with the refrigeration load calculation and test results.
12- Producing prototypes as trial production at the first phase, and mass production after successfully production of trial products and analyzing, data collected from performance of trial product. Minimum 300 units of trial production is recommended.

Method of Refrigeration Load Calculation

Refrigeration load consist of four individual components:

1- Transmission load;

Heat transfer through walls (sides, back panels, top and bottom) and door panel.

2 - Product load;

Heat Removed from and produced by the products which are brought and stored in the refrigerator;

3 - Internal load;

Heat produced by internal sources such as lights, fan or heaters;

4 - Infiltration load

Heat gains associated with air entering the refrigerated space;

Transmission Load

Heat gain through walls of a refrigerated space depend on cabin Temperature, liner, insulation and cabin conductivity and also the surrounded ambient air. In other word, there are four different resistance opposing heat flow between cabin space and ambient air as given in resistance circuit.

"T" refrigerator ⇦ ("R"liner + "R"insulation + "R"cabin + "R"ambient) ⇦ "T"ambient

"T" evaporator ⇦ ("R"liner + "R"insulation + "R"cabin + "R"ambient) ⇦ "T"ambient

"T" = Temperature
"R" = Resistance

Considering the above mentioned resistance, Rl, Rc and Ra are not comparable in magnitude with Ri (Insulation resistance) and so can be neglected in our calculations. Therefore, the resultant circuit and related equations is.

$R = \frac{x}{KA}$ Heat Resistance, and $Q = \frac{\Delta T}{R}$ Heat Transfer

Where:

x = Insulation Thickness, mm
K = Insulation Conductivity, $/m^2 {}^\circ C$
A = Outside Area, m^2
ΔT = Temperature difference ($T_a - T_c$), °C

If the insulation thickness of side walls, back panels, top, bottom and door are different, heat transfer for each part can be calculated separately and then summed for two door refrigerators, due to different cabin temperature of freezer and refrigerator compartments, heat transfer for each compartment should be calculated separately and then added together.

Product Load

Heat removed from products (meat, fruits, vegetables, water and etc.) to reduce temperature from receiving to storage temperature is known as product load. Following steps should be taken to calculated of product loads.

1 - Heat removed from initial temperature (T_i) to storing temperature (T_{rs}) in refrigerator compartment is;

$$Q_{rs} = \Lambda C\ (T_i - T_{rs})$$

Where:

Λ = Mass of product, Kg / h

C = Specific heat of product, Kcal / Kg

2 - Heat removed from intial temperature (T_i) to freezing temperature (T_f) is ;

$$Q_{af} = \Lambda C\ (T_i - T_f)$$

Where :

Λ = Mass of product, Kg / h

C = Specific heat of product above freezing point, Kcal / Kg

3 - Latent heat of fusion for products is equal to;

$$Q_L = \Lambda h$$

Where; h = Latent heat of product, Kcal / Kg

4 - Heat removed from freezing temperature (Tf) to final storage temperature (T_{fs}) is;

$$Q_{bf} = \Lambda C_{bf}\ (T_f - T_{fs})$$

Where:

C= Specific heat of products below freezing temperature.

For upright freezers or freezer compartment of refrigerators, total product load is

$$Q_{pl} = Q_{af} + Q_l + Q_{bf}$$

For storage products to some lower temperatures above freezing temperature in refrigerator compartment is;

$$Q_{pl} = Q_{rs}$$

Internal Load

Electrical energy dissipated in the refrigerated space such as lights, fan motors, heaters, are included in the internal heat load. Due to the little amount of consumption of lighting, the effect of lighting can be negligible and only electrical heaters of two door refrigerators or fan motors (if exist) are considered in our load calculation.

Infiltration Load

Infiltration air load is the heat transfer due to exchanging of refrigerated air with ambient caused by opening of the door or leakage through the gasket area. Infiltration load is one of the most important load components and roughly it is about 20 % of total refrigeration load.

Total Refrigeration load

As it was mentioned before, transmission load (Qtl), product load (Qpl) and internal load (Q il) can be calculated separetely. For infiltration load (air exchange through doorways or gasket leakage), we take into account 25% of sum of the above mentioned components. (transmission load, product load and internal load). Therefore total refrigeration load can be expressed as:

$$Q_{TL} = 1.25\,(Q_{TL} + Q_{PL} + Q_{IL})$$

Equipment Selection

Calculation of refrigeration load is the basis for selecting system equipment. First step is selection of a suitable compressor with cooling capacity comparable to calculated load, then a capillary tube should be selected so that the compressor and tube fix a balance point at the desired evaporating temperature, also two evaporator and condenser should be selected to balance compressor capacity.

Compressor selection

Assuming 16 hours daily operating time for the compressor, the calculated refrigeration load will be modified to:

$$Q_c = \frac{\quad}{16}$$

Where :

Q_c = required cooling capacity

For selection of compressor from manufacturer's catalogue, we have to mention appropriate evaporating temperature;

- In refrigerators with ice compartment mounted inside, maximum evaporating temperature can be selected in order to have - 12 °C (Two Stars) inside ice compartment.

- For upright freezers or freezer compartment of two door refrigerators, evaporating temperature should be in order to obtain -18 °C (Three Stars) cabin temperature.

Capillary tube

Capillary tube is one of the most important components in refrigerator circuits capillary acts as a pressure reducing device to meter the flow of refrigerant to the low pressure side (evaporator) of the system. In other word, capillary tube should be capable to pass refrigerant pumped by he compressor and feed it to evaporator at available load and demand conditions.

On the contrary of the R12 or R22 refrigerants, practical equations, charts or graphs are not available for calculation of capillary size in R134a refrigeration circuits. Comparing saturation properties of R134a with R12 at a certain temperature, R134a pressure is less than

R12, therefore, capillary tube for R134a shall be adjusted at low evaporating temperatures in comparison with R12 system. The capillary for R134a refrigeration system must have an increase resistance which can be estimated about 10 - 15% increase in length for a definite bore. However the exact size (bore and length) can be attainable after laboratory performance tests.

Condenser & Evaporator

The statically cooled condenser is designed for use in small refrigeration appliance with sufficient space for the necessary condenser area. These condensers are manufactured either in tube-on-finned plate type or wire-on-tube design or in body tube. Assuming that compressor casing and tubing will dissipate 80% of the heat equivalent of electrical in put, the condenser should be capable to reject heat absorbed by the refrigerant in the evaporator plus 20% of compressor power input heat equivalent.

The evaporator should balance the selected compressor capacity, not the original calculated load. Most of the refrigerators mainly employ aluminum evaporators produced on the roll-bond principal, where wire-on tube and recently tube in body evaporators are usually installed in upright freezers.

Due to the higher latent heat (h_{fg}) of R134a in comparison with R12 and therefore less refrigerant charge in the system, it seems that evaporators and condensers used for R12 are also suitable for R134a refrigeration system. However more detailed information about role of these two components in the system would be cleared after laboratory performance tests. Therefore partial modifications should be done if needed.

Refrigerant charge

As mentioned in previous sections, R134a latent heat of vaporization is about 28-30% higher than R12 in temperature range -30 C up to + 10 C. Table 2-2 shows thermodynamics saturation properties (with respect to a certain temperature) for these two refrigerants. In practice, charging amount of R134a can be 10-15% less than R12 with the same refrigeration load.

R134a is capable to absorb more humidity of the oil in comparison with R12. Therefore, the filter drier selected for R134a should be a drier with 3A desiccant with 20% more molecular sieve (by weight) in comparison with conventional types.

Model BC-50 Technical Specification

Refrigerator	Type of Product
465 x 520 x 530 mm	Overall Dimension
35 [illegible]	Wall Thickness
P.U. Foam R11 or R141b	Type of Foam
30 Kg/m	Foam Density
110 ISO, 76 Polyol, 24 R11	Foam Mixing Ratio %
46 lit.	Net Internal Volume
Hermetic, Static Cooled	Type of Compressor
41 Watts	Compressor Cooling Capacity
68 Watts	Power Input
0.5 kW//24 hrs	Energy Consumption
Tube, inside body	Type of Condenser
Inside Dim. = 4, Length 4400 mm	Size of Condenser
Roll Bond	Type of Evaporator
1.8 x 2 mt.	Size of Capillary Tube
R12 & R134a	Type of Refrigerant
R12, = 32 Gr. R134a, = 30 Gr.	Refrigerant Charge
7 Gr.	Filter Drier Size
110/60 and 220/50	Power Source
- 12 °C	Designated Inside Evaporator Temperature
5 °C	Designated Inside Ref. Temperature
Standard 32 °C	Designated Operating Condition

Refrigeration Load Calculation
Refrigerator Model BC-50

a) Transmission load calculation

Refrigerator Compartment	Dimension Cm.	Area (sq.mt.)	Insulation Thickness	Temp. Difference
Side Walls	2 x (46.5x52)	0.484	35 mm	27 c
Back Panel	52x53	0.276	35mm	27 c
Top Surface	46.5 x 53	0.246	35mm	27 c
Bottom Surface	46.5 x 53	0.246	35mm	27 c
Door	52 x 53	0.276	35mm	27 c

Insulation Type: Pu Foam with cyclopentane blowing agent.

Thermal Conductivity for Foam = 0.0195 W/ mt. ° C

Thermal Conductivity for Air at -12 at 1 atm. =0.02367 W/mt. ° C

Temperature Difference Refrigerator Compartment:

$\Delta T = 32 - (+5) = 27\ °C$

Ambient Temperature = 32 °C

Refrigerator Air Temperature = +5 °C

Calculation :

Heat Leak For Refrigerator Compartment.

$$Q_{TL} = Q_{SW} + Q_{back\ Panel+\ door} + Q_{Bottom\ +\ Top}$$

$$Q = U\,A\,(T_a - T_r)$$

$$U = K1 / X1$$

Where :

U = Heat Resistance Coefficient Factor

K_1 = Foam Thermal Conductivity

Note : Due to the short thickness of cabinet out side panel (0.6 mm) and plastic inner liner (1.5 mm) heat resistance of these materials have been considered negligible.

Therefore:

1-$Q_{SideWalls} = [U A (T_a - T_r)]$

T_a = Ambient Temperature
T_r = refrigerator air Temperature

U = 1 / (0.035/ 0.0195) = 0.56 W/ sq.m °C

A = 0.484 Sq. Mt.,
T_a = 32 °C
T_r = + 5 °C
therefore
$Q_{SideWalls}$ = 0.56 x 0.484 x 27 = 7032 Watts

$Q_{SideWalls}$ = 7.32 Watts

2 -$Q_{Back\ panel\ and\ Door} = [U A (T_a - T_r)]$

U = 0.56 w/sq. Mt. °C,
$T_a - T_r$ = 27
A = 2 x 0.276

$Q_{Back\ panel\ and\ door}$ = 0.56 x 2 x 0.276 x 27 = 8.3 Watts

$Q_{Back\ panel\ and\ door}$ = 8.3 Watts

3 -$Q_{Top\ and\ Bottom\ Surface} = [U A (T_a - T_r)]$

U = 0.56 w/sq. Mt. °C,
$T_a - T_r$ = 27
A = 2 x 0.246

$Q_{Top\ and\ Bottom\ Surface}$ = 0.56 x 2 x 0.246 x 27 = 7.44 Watts

$Q_{Top\ and\ Bottom\ Surface}$ = 7.44 Watts

Total Refrigerator Heat Leak = 7.32 +8.3 +7.44 = 23 W

Note; due to the small size of evaporator compartment and small heat transfer area around it. We neglected the heat leak difference of 5 degree

Ice Making Capacity

We have considered 0.5 Kg of Ice to be made by the evaporator at standard condition in a period of 24 hrs.

Therefore.

$$Q_{\text{Ice Making}} = \mathbf{m\ c\Delta T}$$

Where: m = mass of water in Kg to be frozen to zero degree centigrade, c = specific heat of water, and ΔT = temperature difference between water and ice temperature.

$Q_{\text{Ice Making}}$ = 0.5 x 1 x 15 = 7.5 Kcal/hr x 1.163 = 8.7 watts x 24 = 208.8 watts/24 hrs

Considering 16 hours of compressor running time. 208.8 ÷16 = 13 watts/hr

Q_{Total} = 23 + 13 = 36 Watts

Considering 20 % of Q total for door opening and heat transfer through gaskets.

$Q_{\text{Grand Total}}$ = 36 + 20%(36) = **43.2** watts

With respect to the above refrigeration load calculation, the suitable compressor should be compatible with R12 compressor model Daewoo SL9Y-5, for evaporating temperature of – 10 °C.

Model BC-80 Technical Specification

Refrigerator	Type of Product
465 x 520 x 760 mm	Overall Dimension
35 mm	Wall Thickness
P.U. Foam R11 or R141b	Type of Foam
30 Kg/m	Foam Density
110 ISO, 76 Polyol, 24 R11	Foam Mixing Ratio %
80 lit.	Net Internal Volume
Hermetic, Static Cooled	Type of Compressor
50 Watts	Compressor Cooling Capacity
78 Watts	Power Input
0.5 kW//24 hrs	Energy Consumption
Tube, inside body	Type of Condenser
Inside Dim. = 4, Length 6500 mm	Size of Condenser
Roll Bond	Type of Evaporator
1.8 x 2 mt.	Size of Capillary Tube
R12 & R134a	Type of Refrigerant
R12, = 50 Gr. R134a, = 43 Gr.	Refrigerant Charge
7 Gr.	Filter Drier Size
110/60 and 220/50	Power Source
- 12 °C	Designated Inside Evaporator Temperature
5 °C	Designated Inside Ref. Temperature
Standard 32 °C	Designated Operating Condition

Refrigeration Load Calculation
Refrigerator Model BC-80

a) Transmission load calculation

Refrigerator Compartment	Dimension Cm.	Area (sq.mt.)	Insulation Thickness	U	Temp Diff.	Q Watts
Ref. Side Walls	2 x (46.5x64)	0.595	35 mm	0.56	37 c	12.33
Ref. Back Panel	52x64	0.333	35mm	0.56	27 c	5.03
Ref. Door	52 x 64	0.333	35mm	0.56	27 c	5.03
Bottom Surface	46.5 x 53	0.246	35mm	0.56	27 c	3.72
Top Surface	46.5 x 53	0.246	35mm	0.56	44 c	6.10
Evp. Side Walls	2x(46.5x12)	0.112	35 mm	0.56	55 c	3.45
Evp. Backpanel	52x12	0.0624	35 mm	0.56	44 c	1.54
Evp. door	52x12	0.0624	35 mm	0.56	44 c	1.54
Total		1.9898				38.74

Insulation Type: Pu Foam with cyclopentane blowing agent.

Thermal Conductivity for Foam = 0.0195 W/ mt. ° C

Thermal Conductivity for Air at -12 at 1 atm. =0.02367 W/mt. ° C

Temperature Difference Refrigerator Compartment:

~~ΔT = 32 - (+5) = 27 ° C~~

Ambient Temperature = 32 °C

~~Refrigerator Air Temperature = +5 °C~~

Inside Evaporator temperature = - 12 °C

Calculation :

Heat Leak For Refrigerator Compartment.

$$Q_{TL} = (Q_{SW} + Q_{back\ Panel+\ door} + Q_{Bottom})_{ref.} + (Q_{SW} + Q_{back\ Panel+\ door} + Q_{Top})_{Evp.}$$

$$Q = U\ A\ (T_a - T_r)$$

$$U = K1 / X1$$

Where :

U = Heat Resistance Coefficient Factor
K_1 = Foam Thermal Conductivity

Therefore:

1-$Q_{\text{SideWalls ref.}} = [\, U\, A\, (T_a - T_r)\,]$

T_a = Ambient Temperature
T_r = refrigerator air Temperature

$U = 1 / (0.035 / 0.0195) = 0.56$ W/ sq.m °C

A = 0.595 Sq. Mt.,
T_a = 37 °C
T_r = + 5 °C
therefore
$Q_{\text{SideWalls ref.}} = 0.56 \times 0.595 \times 37 = 12.33$ Watts

$Q_{\text{SideWalls erf.}} = 12.33$ Watts

2 -$Q_{\text{Back panel and Door ref.}} = [\, U\, A\, (T_a - T_r)\,]$

U = 0.56 w/sq. Mt. °C,
$T_a - T_r = 27$
A = 2 x 0.333 = 0.666

$Q_{\text{Back panel and door ref.}} = 0.56 \times 2 \times 0.333 \times 27 = 10.07$ Watts

$Q_{\text{Back panel and door ref.}} = 10.7$ Watts

3 -$Q_{\text{Bottom Surface}} = [\, U\, A\, (T_a - T_r)\,]$

U = 0.56 w/sq. Mt. °C,
$T_a - T_r = 27$
A = 2 x 0.246

$Q_{\text{Bottom Surface}} = 0.56 \times 0.246 \times 27 = 3.77$ Watts

$Q_{\text{Bottom Surface}} = 7.44$ Watts

1-$Q_{\text{SideWalls ref.}} = [\, U\, A\, (T_a - T_r)\,]$

T_a = Ambient Temperature
T_r = refrigerator air Temperature

$U = 1 / (0.035/ 0.0195) = 0.56$ W/ sq.m °C

A = 0.595 Sq. Mt.,
T_a = 37 °C
T_f = + 5 °C
therefore
$Q_{\text{SideWalls ref.}} = 0.56 \times 0.595 \times 37 = 12.33$ Watts

$Q_{\text{SideWalls erf.}} = 12.33$ Watts

2 -$Q_{\text{Back panel and Door ref.}} = [\, U\, A\, (T_a - T_r) \,]$

U = 0.56 w/sq. Mt. °C,
$T_a - T_r = 27$
A = 2 x 0.333 = 0.666

$Q_{\text{Back panel and door ref.}} = 0.56 \times 2 \times 0.333 \times 27 = 10.07$ Watts

$Q_{\text{Back panel and door ref.}} = 10.7$ Watts

3 -$Q_{\text{Bottom Surface}} = [\, U\, A\, (T_a - T_r) \,]$

U = 0.56 w/sq. Mt. °C,
$T_a - T_r = 27$
A = 0.246

$Q_{\text{Bottom Surface}} = 0.56 \times 0.246 \times 27 = 3.77$ Watts

$Q_{\text{Bottom Surface}} = 7.44$ Watts

Total Refrigerator Heat Leak = 12.33 +10.07 +3.77 = 26.17 W

1-$Q_{\text{SideWalls evp}} = [\, U\, A\, (T_a - T_r) \,]$

T_a = Ambient Temperature
T_r = refrigerator air Temperature

$U = 1 / (0.035/ 0.0195) = 0.56$ W/ sq.m °C

A = 0.112 Sq. Mt.,

T_a = 32°C

T_f = −23.3°C

therefore

$Q_{\text{SideWalls evp.}}$ = 0.56 x 0.112 x 54 = 3.45 Watts

$$Q_{\text{SideWalls evp.}} = 3.45 \text{ Watts}$$

2 -$Q_{\text{Back panel and Door evp.}}$ = $[\, U\, A\, (T_a - T_r)\,]$

U_f= 2x 1.54. w/sq. Mt. °C,

$T_a - T_r = 44$

A = 2 x 0.0624 = 0.1248

$Q_{\text{Back panel and door evp.}}$ = 0.56 x 2 x 0.0624 x 44 = 3.08 Watts

$$Q_{\text{Back panel and door evp.}} = 3.08 \text{ Watts}$$

3 -$Q_{\text{Top Surface}}$ = $[\, U\, A\, (T_a - T_r)\,]$

U = 0.56 w/sq. Mt. °C,

$T_a - T_r = 44$

A = 0.246

$Q_{\text{Top Surface}}$ = 0.56 x 0.246 x 44 = 6.06 Watts

$$Q_{\text{Top Surface}} = 6.06 \text{Watts}$$

Total Evaporator Heat Leak = 3.45 +3.08 +6.06 = 12.59

Total Heat Leak = (Refrigerator + Evaporator) = 26.17 + 12.59 = 38.76

Ice Making Capacity

We have considered 0.750 Kg of Ice to be made by the evaporator at standard condition in a period of 24 hrs.

Therefore.

$$Q_{\text{Ice Making}} = m\, c\Delta T$$

Where: m = mass of water in Kg to be frozen to zero degree centigrade, c = specific heat of water, and ΔT = temperature difference between water and ice temperature.

$Q_{\text{Ice Making}}$ = 0.750 x 1 x 15 = 11.25 Kcal/hr x 1.163 = 13.1 watts x 24 = 314 watts/24 hrs

Considering 16 hours of compressor running time. 314 ÷16 = 19.6 watts/hr

Q_{Total} = 38.76 + 19.6 = 58 Watts

Considering 10 % of Q total for door opening and heat transfer through gaskets.

$Q_{\text{Grand Total}}$ = 58 + 10%(36) = **63.8** watts

With respect to the above refrigeration load calculation, the suitable compressor should be compatible with R12 compressor, for evaporating temperature of – 23.3 °C.

Model BCD-112 Technical Specification

Refrigerator and Freezer	Type of Product
465 x 520 x 760 mm	Overall Dimension
35 mm and 60	Wall Thickness
PU Foam R11 or R141b	Type of Foam
30 Kg/m	Foam Density
110 ISO, 76 Polyol, 24 R11	Foam Mixing Ratio %
110 lit.	Net Internal Volume
Hermetic, Static Cooled	Type of Compressor
90 Watts	Compressor Cooling Capacity
110 Watts	Power Input
1 kW//24 hrs	Energy Consumption
Tube, inside body	Type of Condenser
Inside Dim. = 4, Length 12000 mm	Size of Condenser
Plate and Tube	Type of Evaporator
1.8 x 2 mt.	Size of Capillary Tube
R12 & R134a	Type of Refrigerant
R12, = 85 Gr. R134a, = 78Gr.	Refrigerant Charge
9 Gr.	Filter Drier Size
110/60 and 220/50	Power Source
- 18 °C	Designated Inside Evaporator Temperature
5 °C	Designated Inside Ref. Temperature
Standard 32 °C	Designated Operating Condition

Refrigeration Load Calculation
Double Door Refrigerator and Freezer Model BCD-112

a) Transmission load calculation

Refrigerator Compartment	Dimension Cm.	Area (sq.mt.)	Insulation Thickness	U	Temp Diff.	Q Watts
Ref. Side Walls	2 x (48x68)	0.653	35 mm	0.56	37 c	13.5
Ref. Back Panel	46x68	0.313	35mm	0.56	27 c	4.73
Ref. Door	46x68	0.313	35mm	0.56	27 c	4.73
Bottom Surface	46x48	0.221	35mm	0.56	27 c	3.34
Top Surface	46x48	0.221	60mm	0.32	50 c	3.52
Frz. Side Walls	2x(48x42)	0.403	60 mm	0.32	60 c	7.74
Frz. Backpanel	46x42	0.193	60 mm	0.32	50 c	3.09
Frz. door	46x42	0.193	60 mm	0.32	50 c	3.09
Total		2.510				43.74

Insulation Type: Pu Foam with cyclopentane blowing agent.

Thermal Conductivity for Foam = 0.0195 W/ mt. °C

Thermal Conductivity for Air at -12 at 1 atm. =0.02367 W/mt. °C

Temperature Difference Refrigerator Compartment:

$\Delta T = 32 - (+5) = 27\ ^\circ C$

Ambient Temperature = 32 °C

Refrigerator Air Temperature = +5 °C

Inside Freezer temperature = -18 °C

$\Delta T = 32 - (-18) = 50\ ^\circ C$

Calculation :

Heat Leak For Refrigerator and Freezer Compartments.

$$Q_{TL} = (Q_{SW} + Q_{back\ Panel+door} + Q_{Bottom})_{ref.} + (Q_{SW} + Q_{back\ Panel+door} + Q_{Top})_{freezer.}$$

$$Q = U A (T_a - T_r)$$

$$U = K_1 / X_1$$

Where :

U = Heat Resistance Coefficient Factor
K_1 = Foam Thermal Conductivity

Therefore:

1-$Q_{\text{SideWalls ref.}} = [\, U A (T_a - T_r) \,]$

T_a = Ambient Temperature
T_r = refrigerator air Temperature

$U = 1 / (0.035 / 0.0195) = 0.56$ W/ sq.m °C

A = 0.653 Sq. Mt.,
$T_a = 32 + 10 = 42$ °C
$T_f = + 5$ °C
therefore
$Q_{\text{SideWalls ref.}} = 0.56 \times 0.653 \times 37 = 13.5$ Watts

$Q_{\text{SideWalls ref.}} = 13.5$ Watts

2 -$Q_{\text{Back panel and Door ref.}} = [\, U A (T_a - T_r) \,]$

U = 0.56 w/sq. Mt. °C,
$T_a - T_r = 27$
$A = 2 \times 0.313 = 0.616$

$Q_{\text{Back panel and door ref.}} = 0.56 \times 2 \times 0.313 \times 27 = 9.46$ Watts

$Q_{\text{Back panel and door ref.}} = 9.46$ Watts

3 -$Q_{\text{Bottom Surface}} = [\, U A (T_a - T_r) \,]$

U = 0.56 w/sq. Mt. °C;
$T_a - T_r = 27$
$A = 0.221$

$Q_{\text{Bottom Surface}} = 0.56 \times 0.221 \times 27 = 3.34$ Watts

$Q_{\text{Bottom Surface}} = 3.34$ Watts

1-Q $_{\text{SideWalls frz.}}$ = [U A (T_a - T_r)]

T_a = Ambient Temperature
T_r = refrigerator air Temperature

U = 1 / (0.060/ 0.0195) = 0.32 W/ sq.m °C

A = 0.403 Sq. Mt.,
T_a = 32 + 10 = 42 °C
T_f = -18 °C
therefore
Q $_{\text{SideWalls frz.}}$ = 0.56 x 0.403 x 60 = 7.74 Watts

Q $_{\text{SideWalls frz.}}$ = 7.74 Watts

2 -Q $_{\text{Back panel and Door frz.}}$ = [U A (T_a - T_r)]

U = 0.32 w/sq. Mt. °C,
T_a - T_r= 50
A = 2 x 0.193 = 0.386 ,

Q $_{\text{Back panel and door ref.}}$ = 0.56 x 2 x 0.193 x 50 = 6.18 Watts

Q $_{\text{Back panel and door ref.}}$ = 6.18 Watts

3 -Q $_{\text{Top Surface}}$ = [U A (T_a - T_r)]

U = 0.32 w/sq. Mt. °C,
T_a - T_r= 50
A = 0.221

Q $_{\text{Bottom Surface}}$ = 0.56 x 0.221 x 50 = 3.52 Watts

Q $_{\text{Bottom Surface}}$ = 3.52 Watts

Total Heat Leak = 13.5+9.46+3.34+3.52+7.74+6.18 = 43.74 W

Ice Making Capacity

We have considered 1 Kg of Ice to be made by the evaporator at standard condition in a period of 24 hrs.

Therefore.

$$Q_{\text{Ice Making}} = m\, c\Delta T$$

Where: m = mass of water in Kg to be frozen to zero degree centigrade, c = specific heat of water, and ΔT = temperature difference between water and ice temperature.

$Q_{\text{Ice Making}}$ = 1 x 1 x 28 = 28 Kcal/hr x 1.163 = 32.56 watts x 24 = 781 watts/24 hrs

Considering 16 hours of compressor running time. 781 ÷16 = 48.8 watts/hr

Q_{Total} = 43.74 + 48.8 = 92.58 Watts

Considering 20 % of Q total for door opening and heat transfer through gaskets.

$Q_{\text{Grand Total}}$ = 92.58 + 20%(18.5) = **111.1** watts

With respect to the above refrigeration load calculation, the suitable compressor should be compatible with R12 compressor, for evaporating temperature of – 23.3 °C.

Performance Test of Prototypes

Three prototypes will be tested in accordance with ISO and Chinese standards under following test condition. The test results will be submitted to UNIDO together with our draft final report. The necessary changes to the refrigeration system circuit will be applied during performance tests. Necessary evaluation is also required for adjustment for optimized energy consumption.

Standard Condition 32 C ambient temperature.

- Pull Down Test
- Continuos Run Test
- Cyclic Run Test

Energy Consumption Test at 32 C ambient Temperature.

All relevant test results sheets will be also enclosed to our draft final report.

Activities

1-Calculation of prototypes models;

Refrigerator Model BC-46,

- This refrigerator is a mini bar refrigerator and has a good market in China, the internal volume of the refrigerator is 46 liter and the energy consumption is low and about 0.5 Kwatt/24 hrs. The R12 refrigerant charge is 37 grams. The calculation results revealed that a compressor with cooling capacity from 48 to 70 watts could be fitted to this model, we suggested LG low back pressure compressor model VS24, with 78 watts cooling capacity
- The total cooling capacity calculated for this model is43.2 watts according to the thermal conductivity of Cyclopentane PU foam which is higher than R12 PU foam. Since the size of refrigerator is too small we believe that no significant energy consumption increase could be assumed, and no further improvement to the foaming jigs and plugs is required.
- Since the amount of refrigerant charge weight in comparison with a normal size refrigerator is low "37 Gram" we think that a very small changes or equal amount of refrigerant charge would be sufficient for R134a. Therefore we charge 33 gram at the beginning and then we try to adjust the amount of refrigerant charge.
- At the beginning of performance test we keep the initial size of Evaporator and Condenser, therefore no modification and adjustment is required to condenser and evaporator.
- We will use an "XH" model filter direr which uses smaller molecular size and is suitable for R134a refrigerant.

Refrigerator Model BC-80,

- This refrigerator is a small size refrigerator, the internal volume of the refrigerator is 80 liter and the energy consumption is low and about 0.5 Kwatt/24 hrs. The R12 refrigerant charge is 43 grams. The calculation results revealed that a compressor with cooling capacity from 60 to 80 watts could be fitted to this model, we suggested LG low back pressure compressor model VS24. The total cooling capacity calculated for this model is 61.3watts, according to the thermal conductivity of

Cyclopentane PU foam which is higher than R12 PU foam. Since the size of refrigerator is small we believe that no significant energy consumption increase could be assumed, and no further improvement to the foaming jigs and plugs is required.

- Since the amount of refrigerant charge weight in comparison with a normal size refrigerator is low "43 Gram" we think that no significant adjustment to refrigerant charge weight will be done. Therefore we charge 43 gram at the beginning and then we try to adjust the amount of refrigerant charge.
- At the beginning of performance test we keep the initial size of Evaporator and Condenser, therefore no modification and adjustment is required to condenser and evaporator.
- We will use an "XH" model filter direr which uses smaller molecular size and is suitable for R134a refrigerant.

Refrigerator and Freezer, Model BCD-112,

- This model is a double door upright refrigerator and Freezer with internal volume of the refrigerator is 110 liter and the energy consumption is about 1 Kwatt/24 hrs. The R12 refrigerant charge is 85 grams. The calculation results revealed that a compressor with cooling capacity from 100 to 110 watts could be fitted to this model, we suggested LG compressor. The total cooling capacity calculated for this model is 101watts, according to the thermal conductivity of Cyclopentane PU foam which is higher than R12 PU foam. Since the size of refrigerator is small we believe that no significant energy consumption increase could be assumed, and no further improvement to the foaming jigs and plugs is required.
- Since the amount of refrigerant charge weight in comparison with a normal size refrigerator is low "85 Gram" we think that no significant adjustment to refrigerant charge weight will be done. Therefore we consider 85 gram charge as initial charging weight, and during the performance test the necessary adjustment will be applied to the refrigeration system.
- At the beginning of performance test we keep the initial size of Evaporator and Condenser, therefore no modification and adjustment is required to condenser and evaporator.
- We will use an "XH" model filter direr which uses smaller molecular size and is suitable for R134a refrigerant.

Refrigerator Model BC-68,

- This refrigerator is a mini bar refrigerator and has also a good market in China, the internal volume of the refrigerator is 68 liter and the power input is 78 watts. The R12 refrigerant charge is 37 grams. The calculation results revealed that a compressor with cooling capacity from 48 to 80 watts could be fitted to this model, we suggested LG compressor model VS24 with 78 watts cooling capacity.

- The total cooling capacity calculated for this model is 43.2 watts according to the thermal conductivity of Cyclopentane PU foam which is higher than R12 PU foam. Since the size of refrigerator is too small we believe that no significant energy consumption increase could be assumed, and no further improvement to the foaming jigs and plugs is required.
- Since the amount of refrigerant charge weight in comparison with a normal size refrigerator is low "37 Gram" we think that a very small changes or equal amount of refrigerant charge would be sufficient for R134a. Therefore we charge 33 gram at the beginning and then we try to adjust the amount of refrigerant charge.
- At the beginning of performance test we keep the initial size of Evaporator and Condenser, therefore no modification and adjustment is r[illegible]uired to condenser and evaporator.
- We will use an "XH" model filter direr which uses smaller molecular size and is suitable for R134a refrigerant.

2- Making Prototypes

According to t[illegible] contract four prototypes were made and two prototypes were tested under the following circumstances.

- ✓ Ambient tempe[illegible]e 32 °C
- ✓ Relativ[illegible] Humidity 70 %
- ✓ Type of test , Performance
- ✓ Purpose of Test, Evaluation of refrigeration circuit components performance
- ✓ Type of compressor, Hermetic, "LG" model VS24 with 78 watts cooling capacity
- ✓ Refrigerant Charge weight 33 grams
- ✓ Type of filter drier, XH type 8 grams
- ✓ Size of capillary tube, 1.8 mm Diameter and 2 meter length.
- ✓ Sub-cool system,
- ✓ Condenser type, inside body condenser,
- ✓ Test duration 410 minutes
- ✓ Starting Current 1.38 kW.
- ✓ Energy Consumption 1.16 kW/24 hrs.
- ✓ Compressor running time 5 minutes, 40%
- ✓ Thermostat setting, medium.

- ✓ Performance test applied to the appliance,
  - ✓ Pull Down test, 1.25 hrs
  - ✓ Continuos Run Test Non
  - ✓ Cyclic Run Test, 5.75 hrs.

3- *Test Evaluation*

a) Pull Down Test

The duration of pull down test was about 75 minutes, the initial inside temperature was about 32 C, after 75 minutes the evaporator air temperature reached to the minimum temperature which is – 20 C, it means that the refrigerator has a good insulation, and minimum energy consumed to reach to the nominal appliance operation. Therefore the pull down test could be considered acceptable.

b) Continuos Run Test

Due to the shortage of time the continuos run test were not performed therefore, no analysis can be done in this regard.

b) Cyclic Run Test

The cyclic run test was performed for 335 minutes, and following data obtained from test results;

Prototype Number__BC-46-PT-01

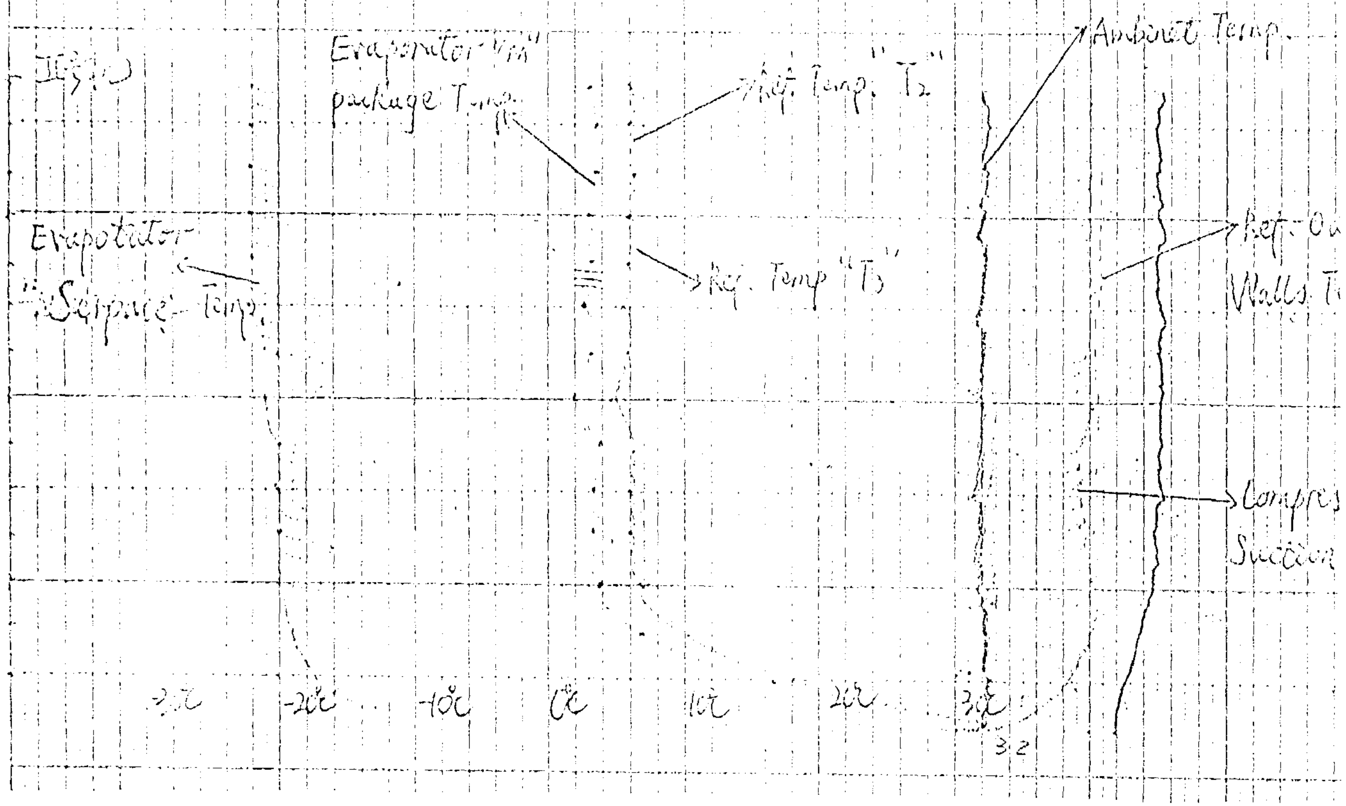
✓ Ambient Temp.	32 C
✓ Relative Humidity	70%
✓ Comp. Type	Hermetic, "LG" VS24
✓ Comp. Cooling Capacity	78 Watts
✓ Comp. Input Power	68 Watt
✓ Refrigerant Charge	R134a, 33 Grams
✓ Filter Direr Weight	8 Grams
✓ Thermostat Setting	Medium
✓ Evaporator Surface Mean Temp.	-22 C
✓ Evaporator Air Mean Temp.	3 C
✓ Refrigerator Air Mean Temp.	5.8 C
✓ Refrigerator Side Wall Temp.	41 C
✓ Compressor Suction Temp.	40 C
✓ Compressor Discharge Temp.	N/A
✓ Compressor Shell Temp.	N/A
✓ Condenser Mid Temp.	41 C
✓ Voltage	220 Volts
✓ Frequency	50 Hrz.
✓ Starting Current	1.38 Amp.
✓ Working Current	N/A
✓ Total Test Run	410 Minutes
✓ Compressor Running Time	40 %
✓ Compressor Running Interval	~ 5 Minutes
✓ Energy Consumption	1.16 Kwatts/24 Hrs
✓	

Prototype Number BC-46-PT-02

✓ Ambient Temp.	32 C
✓ Relative Humidity	70%
✓ Comp. Type	Hermetic, "LG" VS24
✓ Comp. Cooling Capacity	78 Watts
✓ Comp. Input Power	68 Watt
✓ Refrigerant Charge	R134a, 33 Grams
✓ Filter Direr Weight	8 Grams
✓ Thermostat Setting	Medium
✓ Evaporator Surface Mean Temp.	-24 C
✓ Evaporator Air Mean Temp.	4.1 C
✓ Refrigerator Air Mean Temp.	5.7 C
✓ Refrigerator Side Wall Temp.	41 C
✓ Compressor Suction Temp.	53 C
✓ Compressor Discharge Temp.	N/A
✓ Compressor Shell Temp.	N/A
✓ Condenser Mid Temp.	41 C
✓ Voltage	220 Volts
✓ Frequency	50 Hrz.
✓ Starting Current	1.27 Amp.
✓ Working Current	N/A
✓ Total Test Run	410 Minutes
✓ Compressor Running Time	40 %
✓ Compressor Running Interval	~ 5 Minutes
✓ Energy Consumption	1.11 Kwatts/24 Hrs

BC-46 [illegible]

Prototype No. Wualing - BC-PT-1



Performance Test Sheet

Test Sheet Number BC-46-PT-1			Date 18-June-1999
Test type	Ambient Temp.	Product Name	Product Serial Number
Performance	32 °C	Refrigerator-BC-46	Prototype No Heating-BC-PT-1
Type of Compressor	Compressor Model	Compressor Cooling Capacity	
Hermetic "LG"	VS24	41 watt	
Compressor Input Power	Refrigerant Type	Refrigerant Charge Weight	
68 watt	R134a	33 grams	
Condenser Type and Length	Evaporator Type	Capillary Tube Length	
Tube inside The Body	Roll Bond	1.8 x 2 mt.	
Thermostat Type	Thermostat Setting	Test Run Time	Drier Type
Defrost	Medium	7 Hrs	XH7
Drier Weight	8 gram	Relative Hum.%	
		70%	

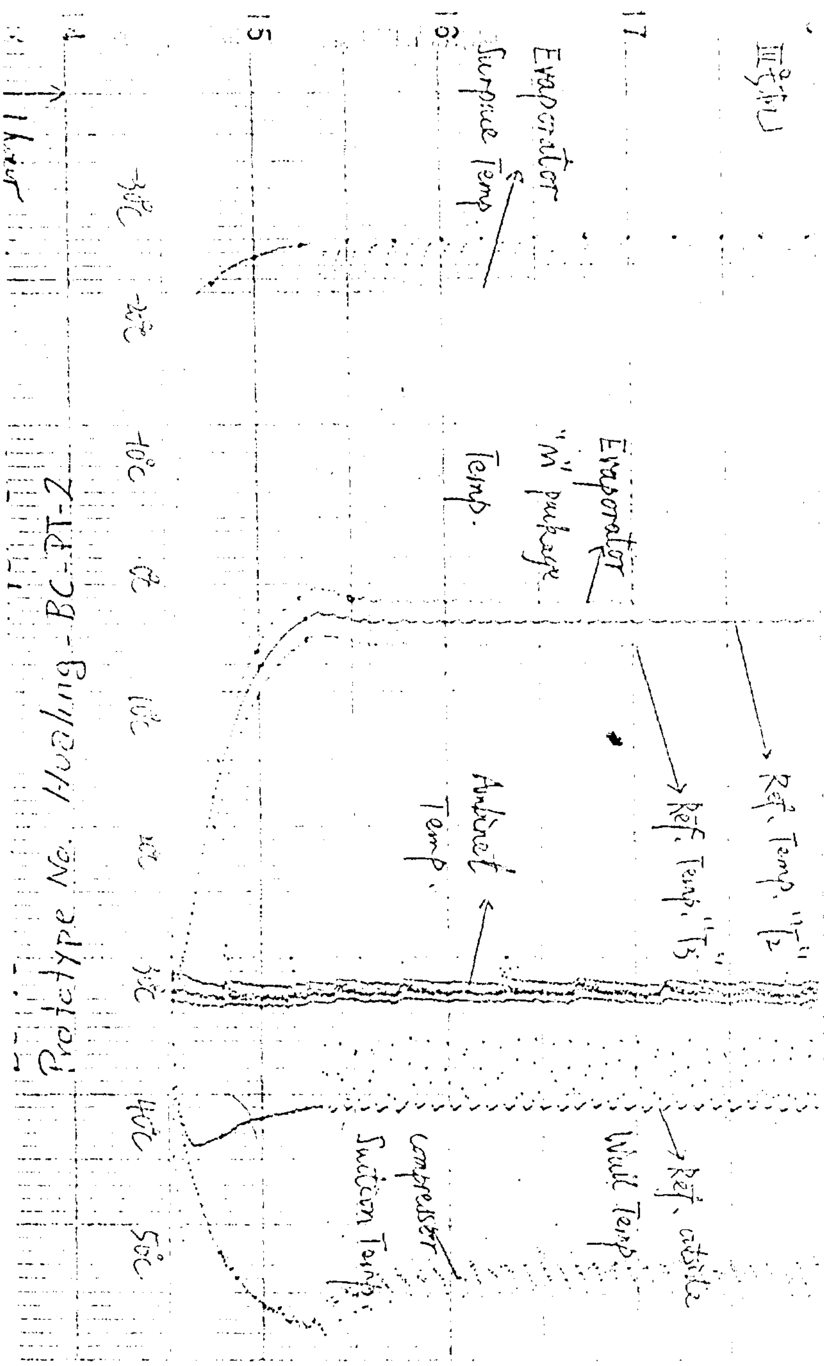
Test Results

Description	30'	60'	90	120	150	180	210	240	270	300	330	360	390	410
Evaporator Surface Temp	-17.5	-19	-20	-20	-20	-20	-21	-20	-21	-22	-22	-22	-22	-22
Evaporator "M" Package Temp	16.5	6.5	4	3.5	3.5	3.8	2	3	2.9	3	3	3.4	3.5	3
Ref. Temp. "T2"	18	10	7	6	6	6.1	5	5.8	5.7	5.9	6	6.1	6.1	6
Ref. Temp. "T3"	18	10	7.5	5.5	5.5	5.6	4.5	5.3	5.2	5.4	5.5	5.6	5.6	5.5
Ref. Mean Temp.	18	10	7.2	5.7	5.7	5.9	4.7	5.5	5.4	6.2	5.4	5.8	5.8	5.7
Ref. Outside Walls Temp.	32	41	40.5	40.5	40.5	40.5	41	40.5	40.5	41	41	41	41	41
Compressor Suction Temp.	38	40	40.5	39	39	39	40	39	40	40	40	40	40	40
Compressor Discharge Temp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Compressor Shell Temp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Condenser Mid Temp.	41	41	41	41	41	41	41	41	41	41	41	41	41	41

Test Result Analysis

Voltage Hertz	Starting Working Current	Energy Consumprion	Remarks
220 50	1.38	1.16 KW/24hr	

Total Time Elapsed for Test Results	Compressor Running Time Perecentage
410 min.	5 min. 40%
Hot Chamber Operator Date and Signature	Laboratoy Manager Signature
(signature)	


Prototype No. Heating - BC-PT-2
1 hour
14
15
16
17
-30°C
-20°C
-10°C
0°C
10°C
20°C
30°C
40°C
50°C
Evaporator Surface Temp.
Evaporator "M" package Temp.
Ambient Temp.
Ref. Temp. "T2"
Ref. Temp. "T3"
Ref. outside Wall Temp.
compressor Suction Temp.

Performance Test Sheet

Test Sheet Number	BC-46-PT-2	Date	19-June-1999

Test type	Ambient Temp.	Product Name	Product Serial Number
Permance Test	32°C	Refrigerator-BC-46	Prototype No. Hualing-BC-PT-2

Type of Compressor	Compressor Model	Compressor Cooling Capacity
LG	VS24	41 watt

Compressor Input Power	Refrigerant Type	Refrigerant Charge Weight
68 watt	R134a	33g

Condenser Type and Length	Evaporator Type	Capillary Tube Length
inside body tube	Roll Bond	1.8 x 2 mt.

Thermostat Type	Thermostat Setting	Test Run Time	Drier Type
Defrost	Medium setting	8 hours	XH7
Drier Weight	Relative Humidity		
7 Gram	70%		

Test Results

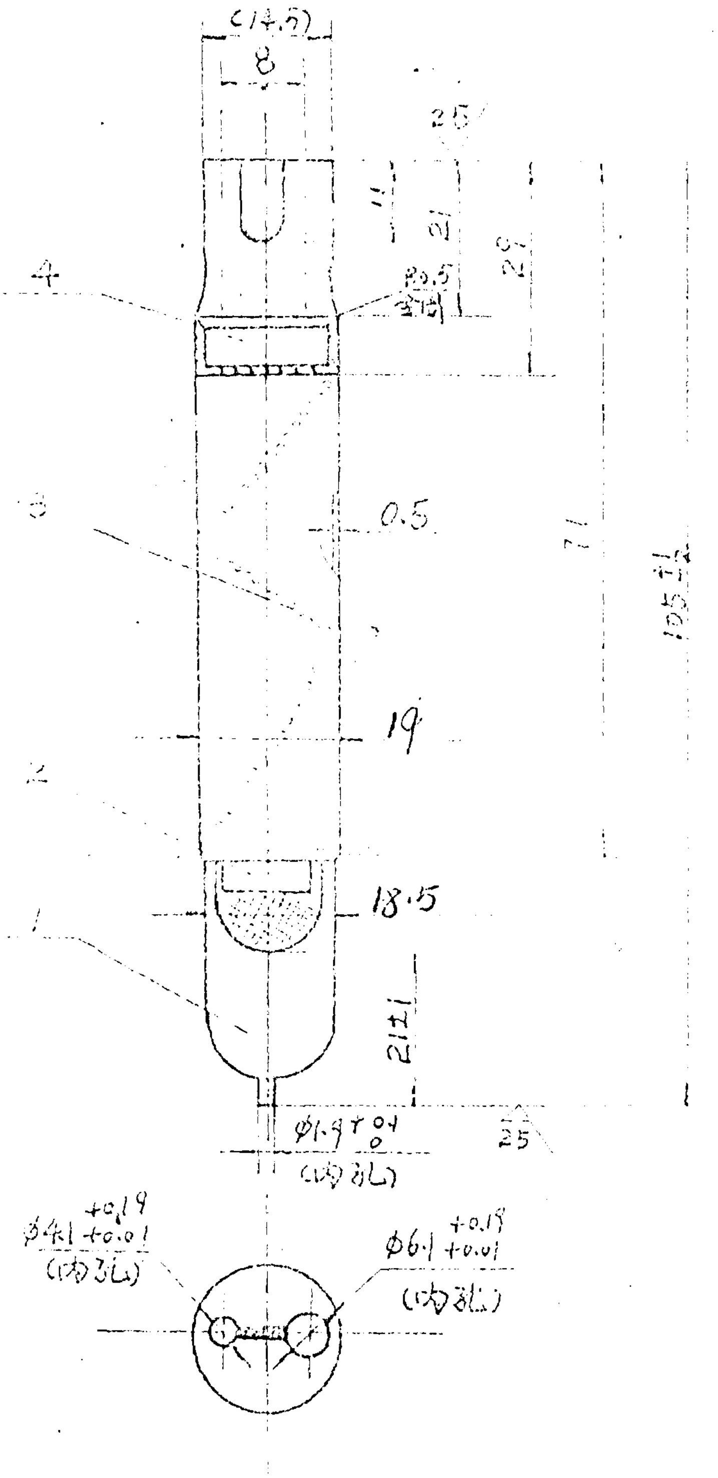
Description	30′	60′	90′	120′	150′	180′	210′	240′	270′	300′	330′	360′	390′	420′
Evaporator Surface Temp	32	-21	-22.5	-23.5	-24	-24	-24	-24	-24	-24	-24	-24	-24	-24
Evaporator "M" Package Temp	32	15	7	4	4	4.1	4.1	4.1	4.1	4.1	4.2	4.1	4.1	4.1
Ref. Temp. "T2"	32	16	8	4.5	4.8	5	5	5	5	5	5	5	5	5
Ref. Temp. "T3"	32	20	10.5	6	6.1	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Ref. Mean Temp.	32	18	14.2	5.2	5.4	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Ref. Outside Walls Temp.	32	43	41.8	41	41	41	41	41	41	41	41	41	41	41
Compressor Suction Temp.	32	52	56	57	55	54	54	53	53	53	53	53	53	53
Compressor Discharge Temp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Compressor Shell Temp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Condenser Mid Temp.	32	42	41	41	41	41	41	41	41	41	41	41	41	41

Test Result Analysis

Voltage Hertz	Starting Working Current	Energy Consumprion	Remarks
220V 50Hz	1.27 A	1.11 KWh/24h	

Total Time Elapsed for Test Results	Compressor Running Time Perecentage
7 hours	40%

Hot Chamber Operator Date and Signature	Laboratoy Manager Signature
[illegible]	



技术要求

1. 分子筛：3Å 分子筛 8g.
   球φ1.6~2.5mm>99%
   残留水份<0.08g.
   吸水量>16.5%.
2. 出口过滤网面积大于160mm²。
3. 外壳耐压为25kg/cm²。
4. 残留油脂<1㎎，残留洗净剂<1PPm。
5. 其余技术要求参照图标。
6、制冷剂用R134a.

序号	代号	名称	数量	材料	单件重量	总计重量	备注
4		干燥剂		分子筛			3A
3		滤网					
2		铜管组件		T2			φ19×0.5
1		外壳					

合肥华凌电器有限公司

干燥器

标记	处数	更改文件号	签字	日期
设计			标准化	
制图			审定	
审核			日期	98.12

图样标记 | 重量 | 比例 1:1

共 页 第 页

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合肥华凌电器有限公司
HEFEI HUALING ELECTRICS CO.,LTD

Mrs. M. Latreh, Contract Officer
Purchase and contract officer
General Service Contracts Section
Administration and financial control
Field operation and administration division

Subject: Final Report
Reference: Contract Number 98/240, Project Number MP/CPR/98/047

Dear Mrs Latrech

We have the pleasure to submit to you herewith our final report. Subjected to the contract number 98/240 and referring to UNIDO's project Number MP/CPR/98/047. We hope that this draft will satisfy you and you can consider it approval for draft final report. We also enclose our invoice, which has been prepared inaccordance with the contract.

Sincerely Yours
General Manager
Hualing Company

合肥华凌电器有限公司
HEFEI HUALING ELECTRICS CO.,LTD.